



WRF idealized-roughness response: PBL scheme and resolution dependence

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WRF idealized-roughness response:

PBL scheme and resolution dependence

towards parameterization-aware WRF application ...

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with data from Jake Badger

partial support from X-WiWa and the New European Wind Atlas projects

for NEWA (Dec.2016),
modified from EMS conf.(Trieste 9/2016)

Rough motivation... PBL-schemes and z_0

- WRF sensitivity to surface conditions:
 - **PBL-scheme** response
 - **Resolution** dependence
 - **Reynolds-number** dependence (?)
- Background roughness length (z_0) crucial for e.g.
 - Wind-field generalization (meso- → micro-scale)
 - Surface-layer applications needing surface-fluxes
- Current generalization :
 - Find domain-scale forcing of micro-scale model
 - Need z_0 (forcing via e.g. geostrophic drag-law)
 - (+small perturbations due to $\Delta z_0, \Delta z_{sfc}$)

Ideal WRF simulations: setup

- "Open" horizontal boundary conditions (zero gradients)
- 200*100*(40 or 80) domain
 - x: 100 Water cells and 100 land cells
- input z_0 : between $\sim 0.1\text{mm}$ (Charnock), 10cm over land
- $\langle w'\theta' \rangle_{\text{sfc}} = 0$
- Geostrophic Wind: constant with z
 - \rightarrow neutral wind speed profile in PBL (at least up to $h/2$)
- Inversion height: $h \sim 650\text{m}$
- 4-day simulations with 10-min. output

Mesoscale-models' interaction with 'bottom'

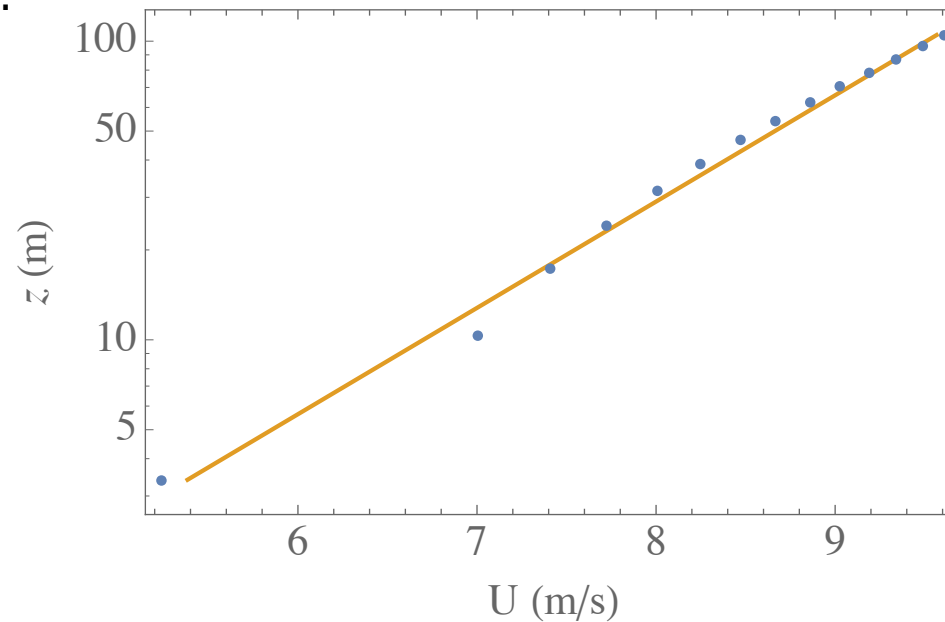
- Calculating effective roughness length

– Bottom 2 levels:

$$\alpha = \frac{dU/dz}{U/z} = \frac{1}{\ln(z/z_{0,\text{eff}})} \quad \rightarrow \quad z_{0,\text{eff}} = \frac{z_1+z_2}{2} \exp \left[-\frac{(U_1+U_2)}{(z_1+z_2)} \frac{(z_2-z_1)}{(U_2-U_1)} \right]$$

– Fit profile to $\ln(z/z_{0,\text{eff}})$

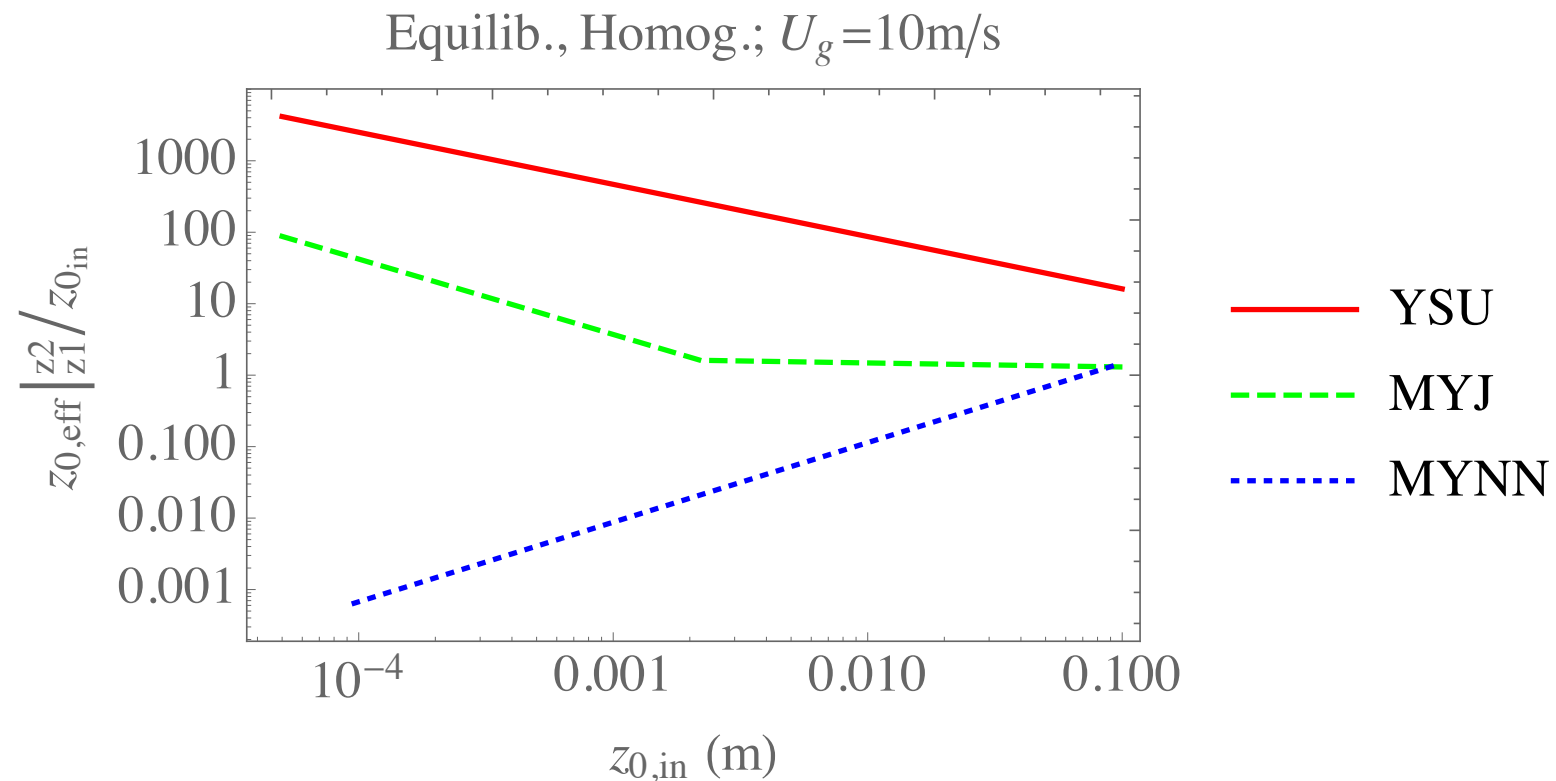
YSU example:



Equilibrium z_0 -response : from bottom-2 levels

(homogeneous domains, $G=10$ m/s)

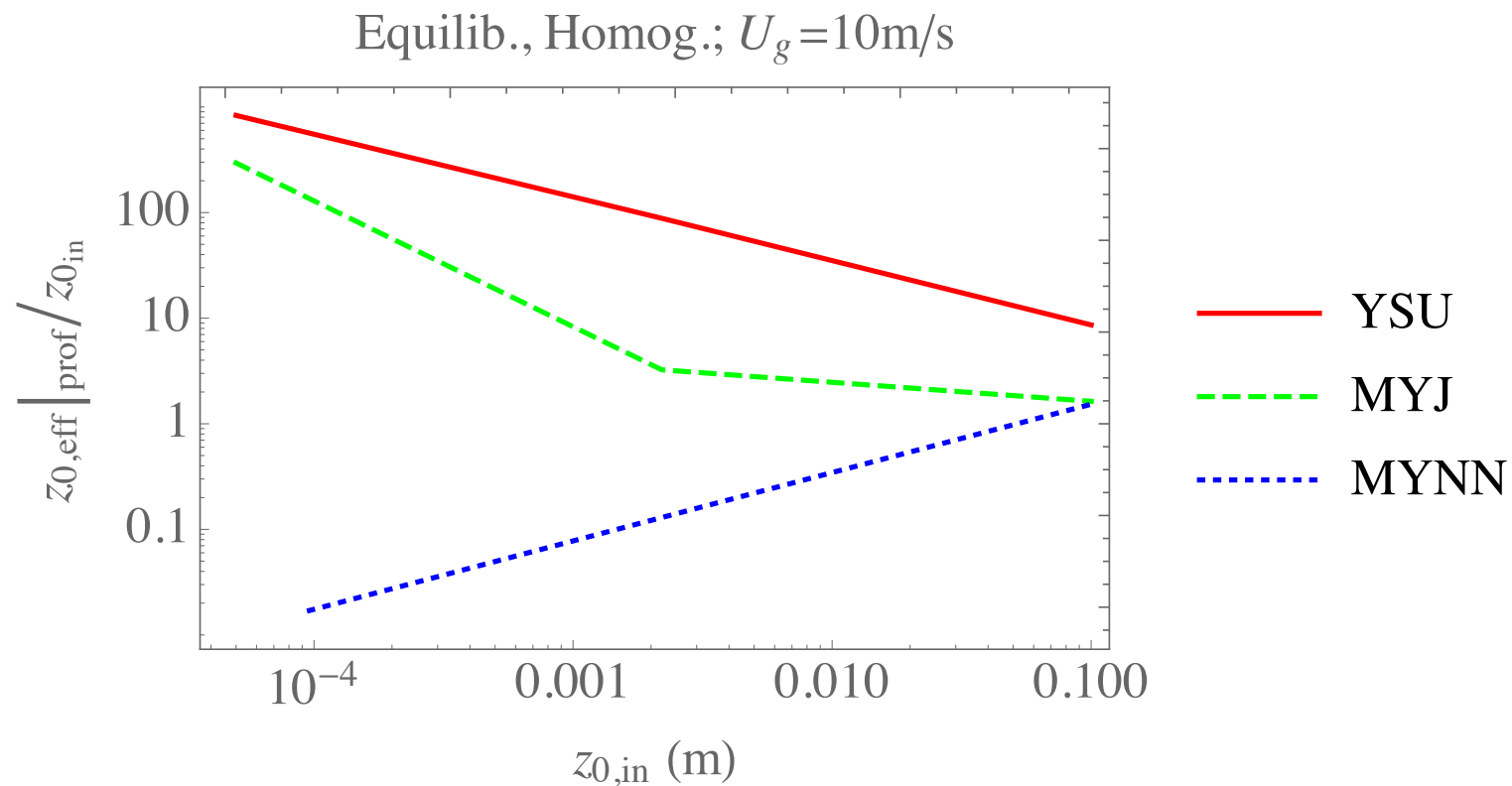
→ No resolution dependence



Equilibrium z_0 -response : from wind profiles

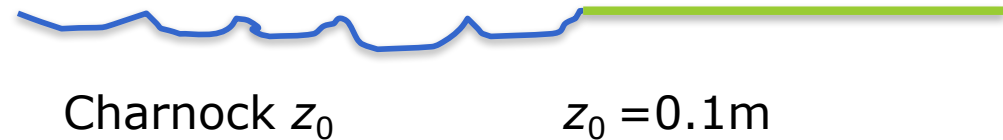
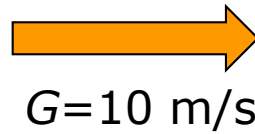
(homogeneous domains, $G=10$ m/s)

→ No resolution dependence

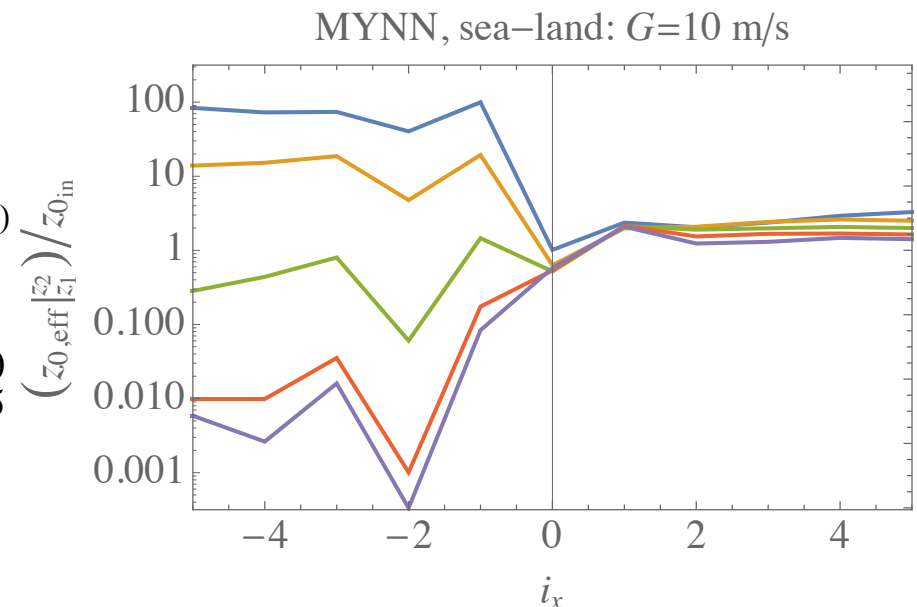
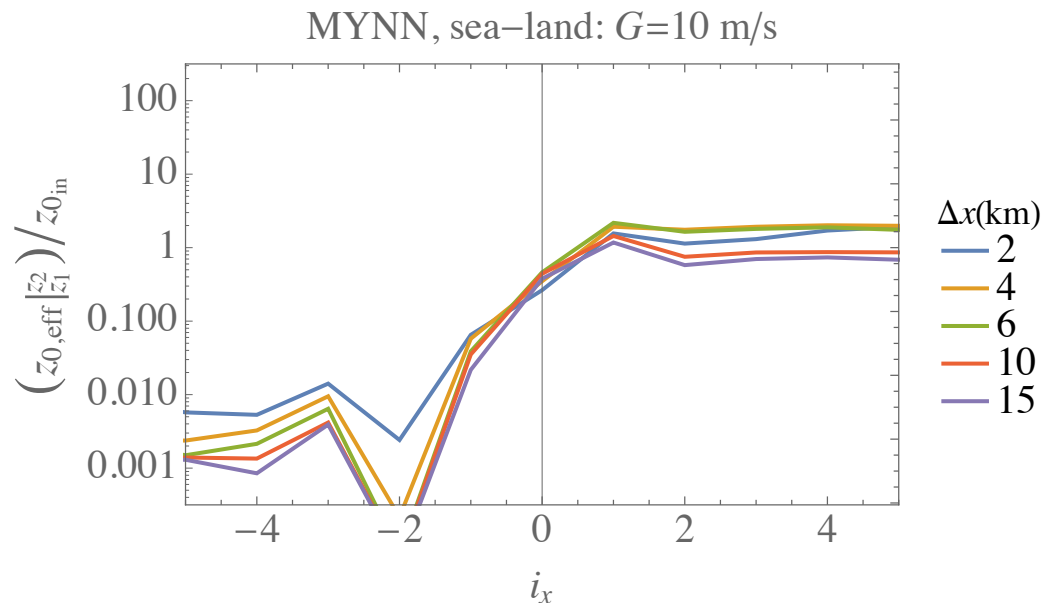


z_0 pseudo- / non-equilibrium via U_1, U_2

- Sea-to-land case

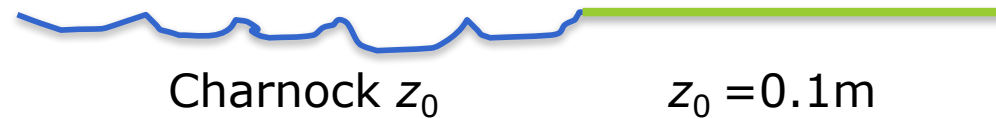
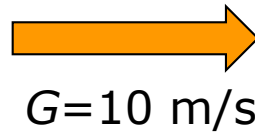


- Different response!
 - M-Y schemes: Resolution-dependence

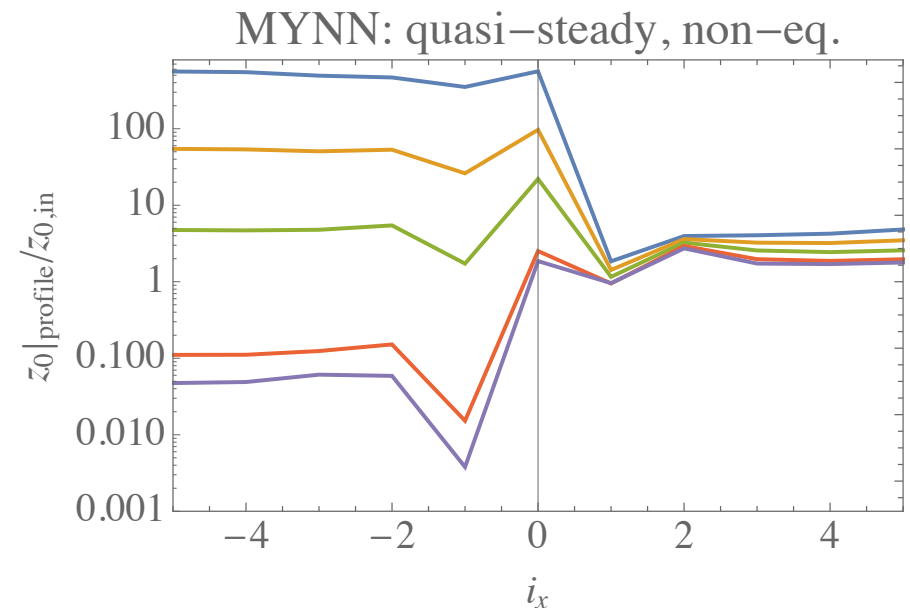
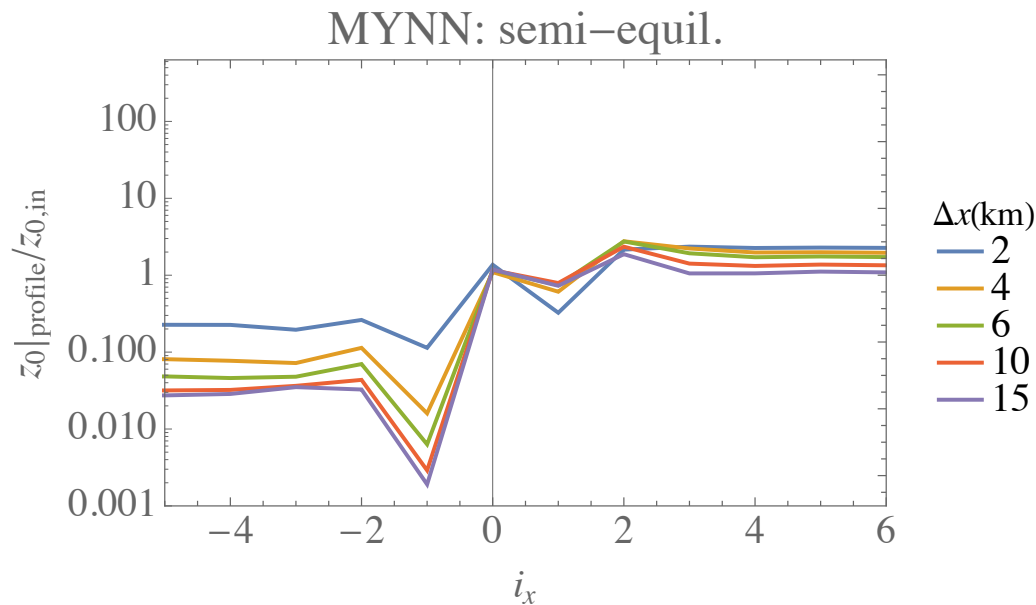


z_0 pseudo- / non-equilibrium via $U(z)$ profiles

- Sea-to-land case



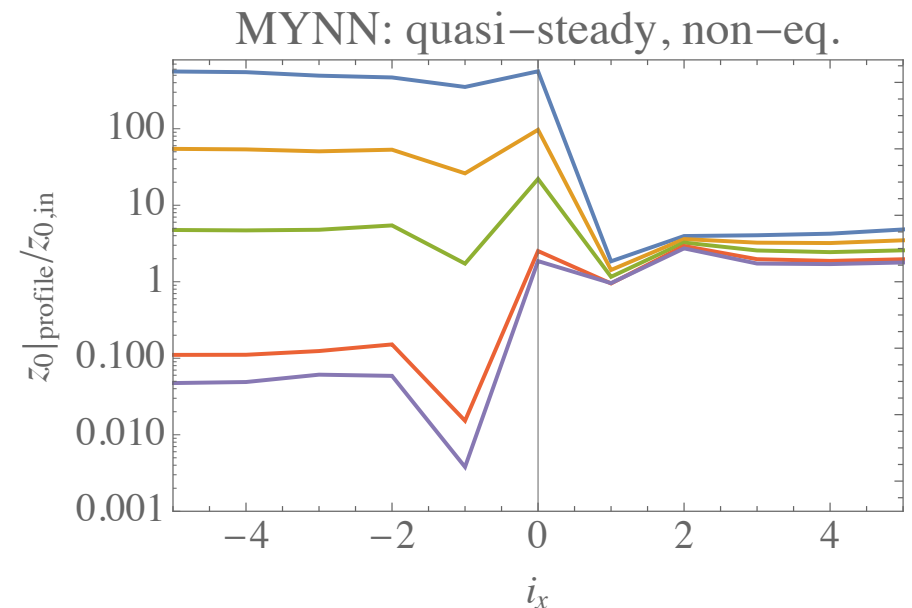
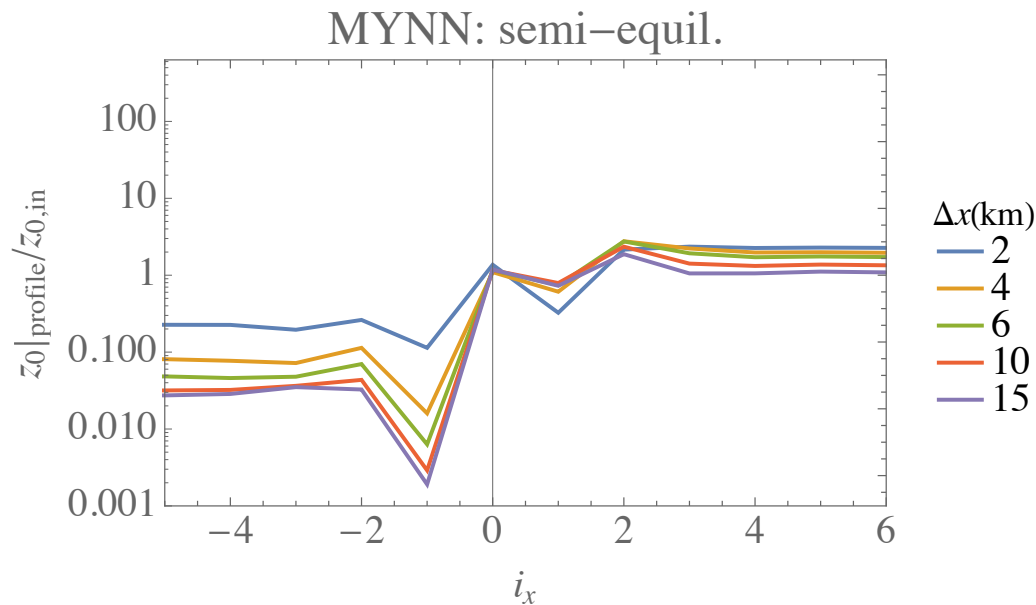
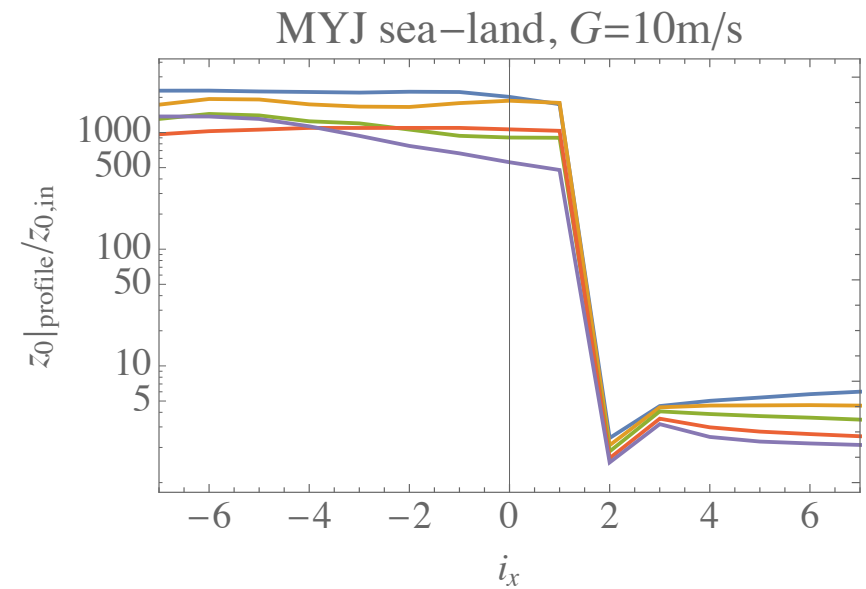
- M-Y schemes: Resolution-dependence



z_0 pseudo- / non-equilibrium via $U(z)$ profiles

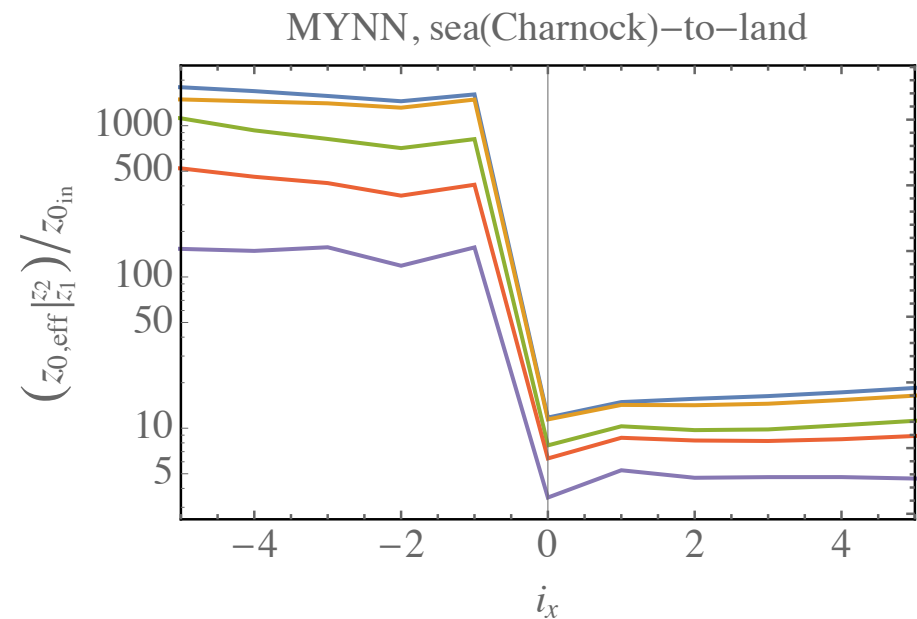
- Sea-to-land case , $G=10$ m/s

- **M-Y schemes:**
Resolution-dependence



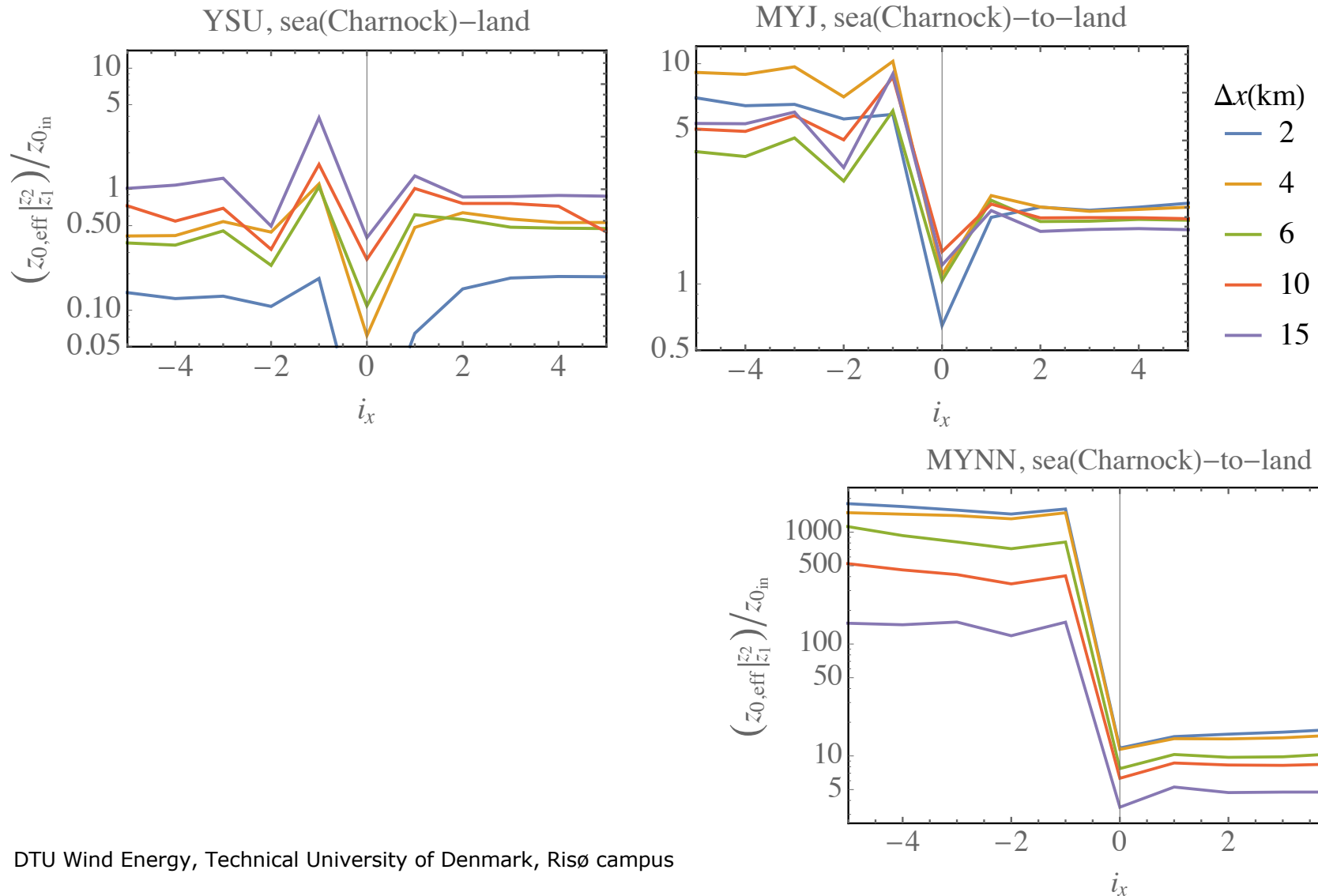
Non-equilibrium z_0 -response via U_1, U_2

Sea-to-land now for $nz=40$: vertical-resolution dependence



Non-equilibrium z_0 -response via U_1, U_2

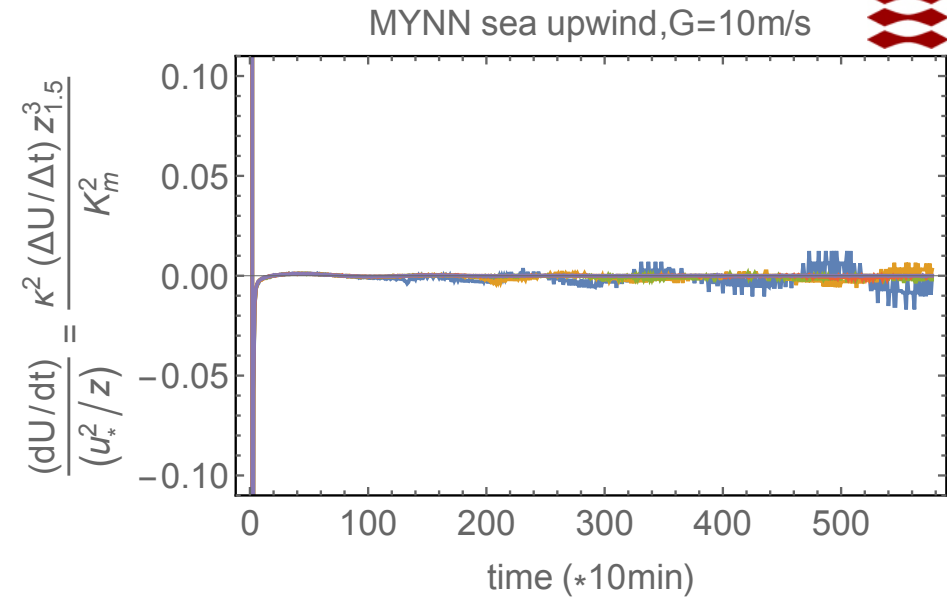
Sea-to-land now for $nz=40$: vertical-resolution dependence



Can we really infer a z_0 ?

- Non-equilibrium, but quasi-steady:

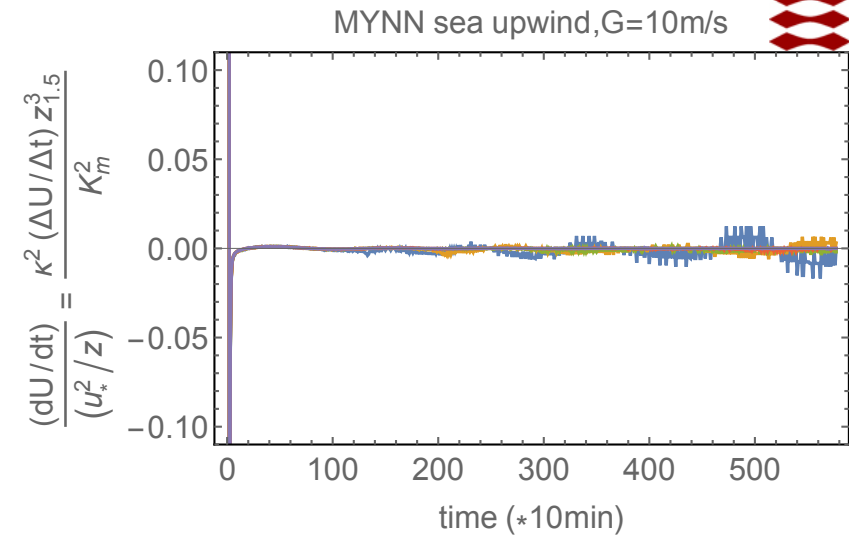
$$\frac{dU}{dt} \ll \frac{u_*^2}{z}$$



Can we really infer a z_0 ?

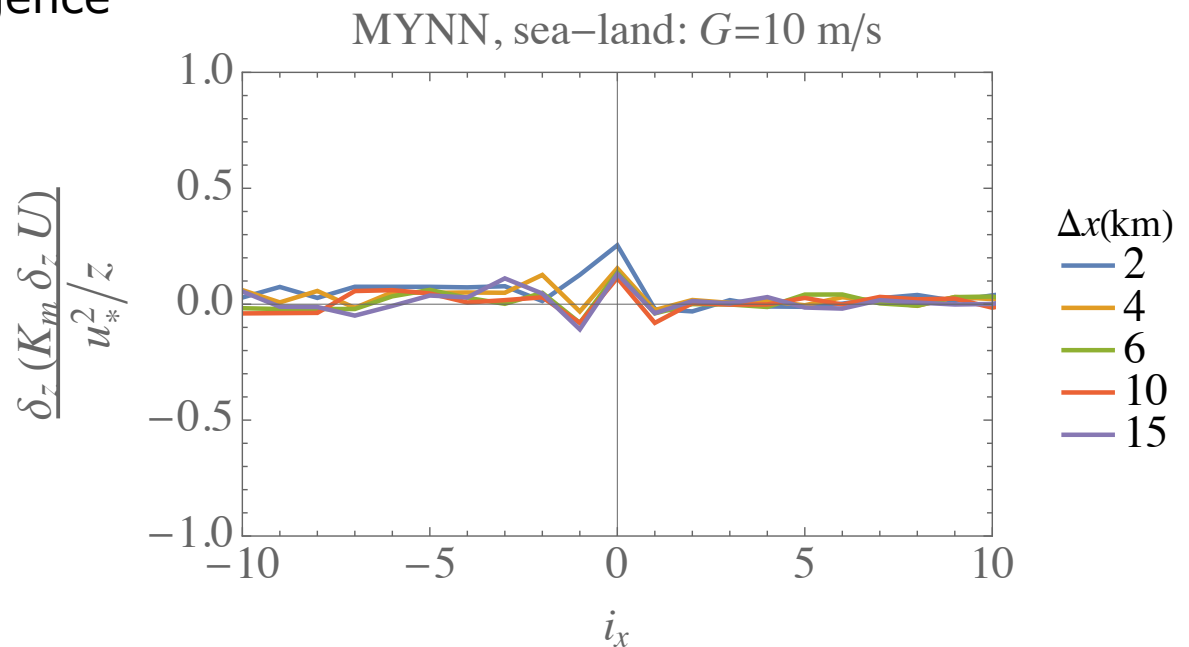
- Non-equilibrium, but quasi-steady:

$$\frac{dU}{dt} \ll \frac{u_*^2}{z}$$



- Normalized stress-divergence

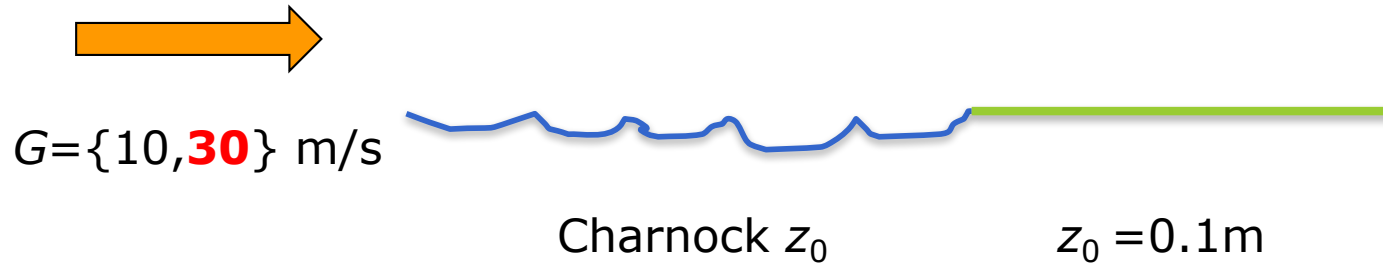
$$\frac{d\tau_{13}}{dz} \ll \frac{u_*^2}{z}$$



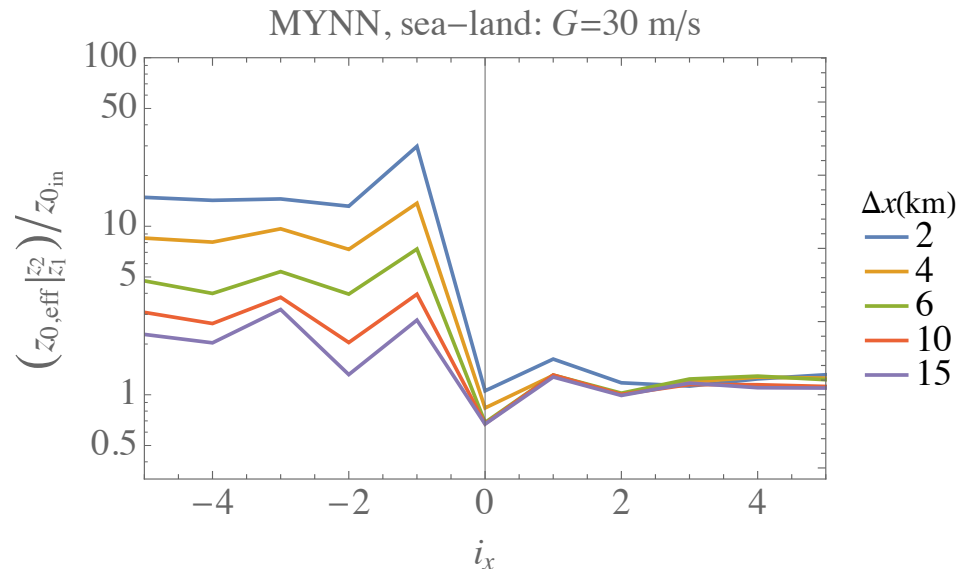
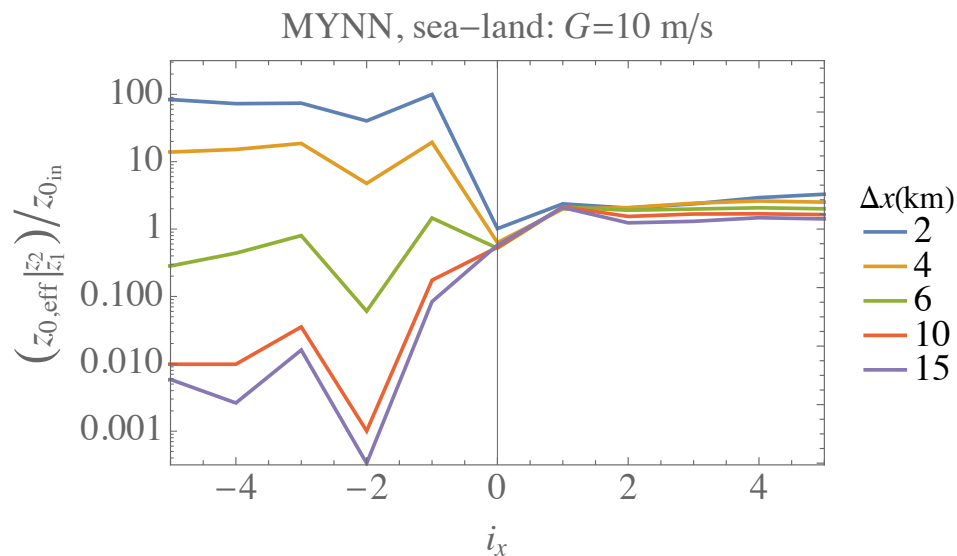
z_0 non-equilibrium : U -dependence

via $U(z)$ profiles

- Sea-to-land case



- Now speed and resolution-dependence



Non-equilibrium z_0 -response : from profiles

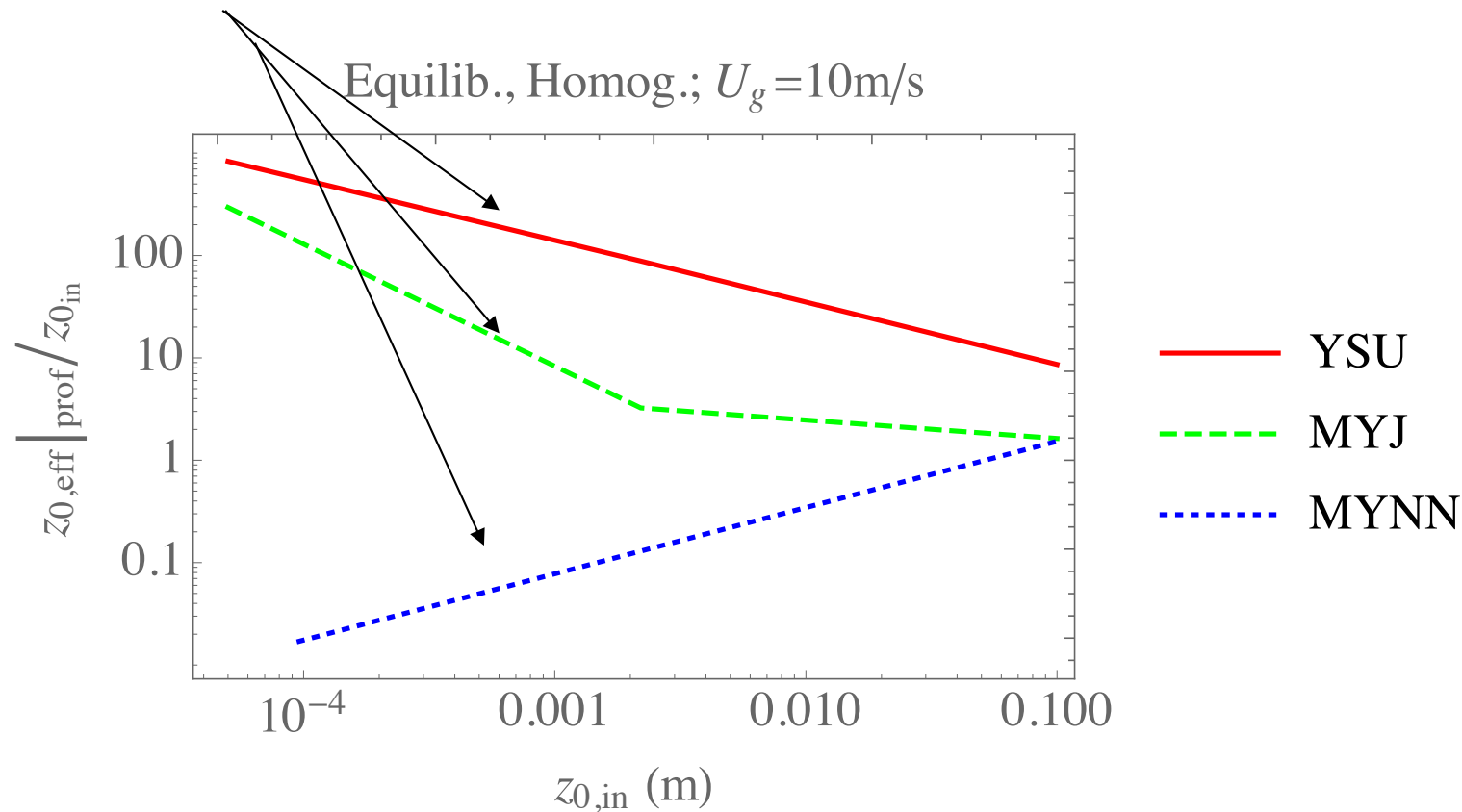
For higher wind speeds

→ Resolution dependence reappears

Compared to *equilibrium response*:

MYNN line moves upward

M-Y lines split, per resolution, as U increases



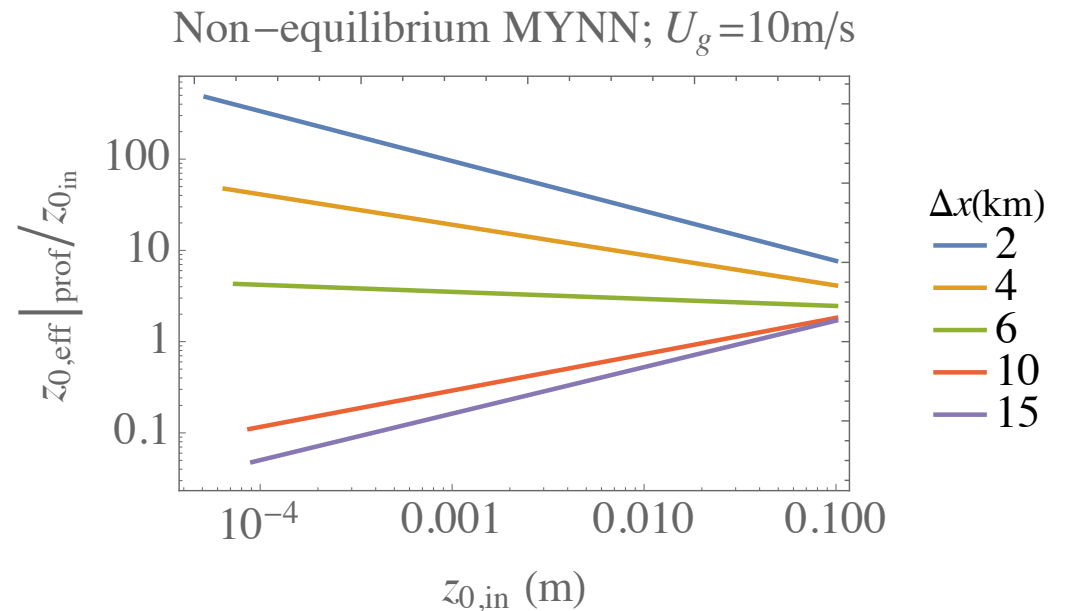
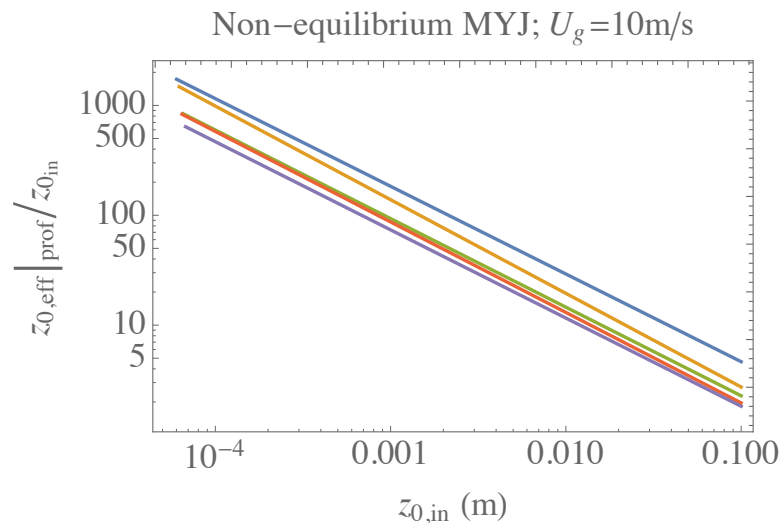
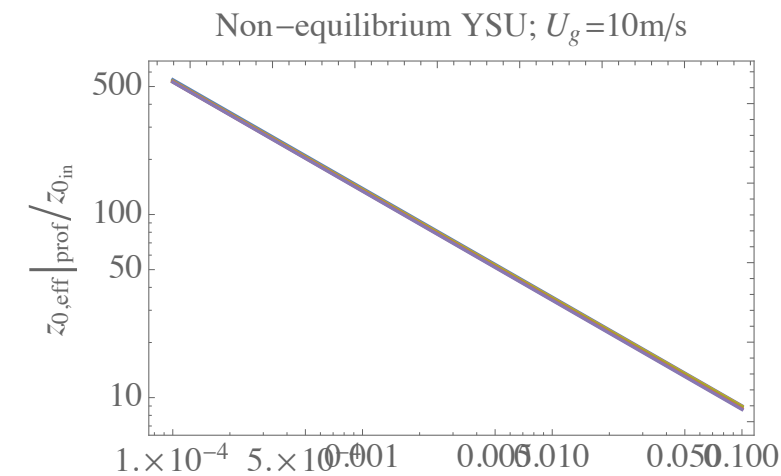
Non-equilibrium z_0 -response : from profiles

For higher wind speeds

→ Resolution dependence reappears

MYNN line moves upward for fine resolutions

Each line here splits, per resolution, more as U increases



Summary

- Equilibrium response: no $z_{0,\text{eff}}(\Delta x)$ –as expected
 - Differs per scheme
- Non-equilibrium response is different from equilibrium response
 - Δx -dependence (resolution, per scheme)
 - schemes appear tuned for some nz : Δz -dependence
 - Speed dependence appears for higher winds
- ...further developments (in progress)
 - More complete z_0 -“mapping” (more $\{z_0, U\}$ regimes)
 - Geostrophic drag-law [GDL] parameter optimization
- leads to (for NEWA/partners/products):
 - filtering z_0 maps for coasts per PBLs, Δx
 - Approximate scaling of wind speeds per z_0 bias
 - Uncertainty estimate for generalization step